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Effects of Fluid Load on Human Urine Characteristics Related to Workplace Drug Testing

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16. Abstract

During workplace drug testing, urine specimens are also tested for sample dilution, substitution, and adulteration. Often when urine sample validity testing indicates such sample modifications, donors argue that these irregularities are due to medical or health conditions, working conditions, dietary habits, or genetic differences. There is a paucity of data correlating changes in urine characteristics after a fluid load to height, weight, body fat, and resting metabolic rate (RMR). In this study, 5 urine specimens from 12 males and 12 females were tested. These specimens were: 1 in the morning, 1 prior to drinking 800-mL of a beverage, and at 3 time intervals thereafter. Beverages tested were water; a fully carbonated, carbohydrate-rich drink; a non-carbonated, electrolyte-rich drink; and a lightly carbonated drink. Of the 480 samples collected, 376 were in sufficient amounts for validity testing. Of these 376 samples, 36 (10%) had creatinine < 20 mg/dL but ≥ 2 mg/dL; 27 (75%) of 36 had specific gravity < 1.0030 but > 1.0010. Thus, these 27 could be considered as "dilute"; 20 (74%) of 27 were obtained from females. For males with at least 1 dilute sample, body fat was 11% less and RMR was 29% more compared to males with no dilute samples ($p > 0.05$); for females with at least 1 dilute sample, height was 8% less and weight 20% less compared to females with no dilute samples ($p > 0.05$). In general, individuals with a higher RMR appear to have a greater potential for producing dilute urine specimens than those with a lower RMR. Thus, a dilute sample does not necessarily indicate that it was intentionally diluted. Such samples must be carefully evaluated in consideration with recent liquid consumption of donors to avoid false accusations of intentionally providing a "dilute" urine sample.

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INTRODUCTION

Under the United States Public Law 102-143 (1) and the Executive Order 12564 (2), individuals working in safety-related positions are subject to random drug testing. According to the procedures for transportation workplace drug testing (3,4), randomly collected urine samples are tested for commonly abused drugs. However, drug users often find ways to defeat the intent of the testing by altering (diluting, substituting, or adulterating) urine specimens. To address this issue, urine validity testing was designed to identify samples that were altered prior to drug testing (3,4).

A urine sample is defined as "dilute" when its creatinine concentration is ≥ 2 mg/dL but < 20 mg/dL and specific gravity is > 1.0010 but < 1.0030 (3,4). The sample is considered "substituted" when its creatinine concentration is < 2 mg/dL and specific gravity is ≤ 1.0010 or ≥ 1.0200. A urine specimen is considered "adulterated" when certain substances are present in the sample at elevated levels. Commonly used adulterants are commercial products containing nitrite, chromium VI, iodide, peroxide, bleach, glutaraldehyde, soap, and acids (5). The majority of adulterants are oxidants, and they act by destroying target analytes. Other adulterants, such as glutaraldehyde, soap, and acids, may interfere with screening assays by destroying enzymes and other proteins, affecting antibody-antigen complex, and/or altering pH. Drug analytical results of a urine sample with a pH value in the range ≥ 3.0 and < 4.5 or ≥ 9.0 and < 11.0 will be reported as invalid (3,6). Urine within either of these pH ranges would be considered non-physiological, since a normal physiological urinary pH range is 4.5 to 8.2 (7).

Some adulterants, such as nitrite, chromium, and iodide, are endogenously present in urine at low concentrations. Consequently, sample donors accused of adulterating their sample argue that those substances are present in elevated concentrations due to a variety of factors including donor's health, working conditions, dietary habits, or differences in body weight, gender, race, and ethnicity. However, whether or not these factors have an effect in causing urine specimens to contain higher concentrations of endogenous substances has yet to be established.

The most controversial aspect of validity testing lies in the possibility that a person may have urine with low creatinine and/or specific gravity because of reasons—dietary habits, ethnic origin, health-related treatments, working conditions, and/or genetic differences—other than an intentional dilution, substitution, or adulteration of the urine sample. To address this issue, the 107th U.S. Congress asked the Department of Transportation (DOT) to conduct a study on drug and alcohol validity testing (8). Subsequently, the DOT Federal Aviation Administration (FAA) held a colloquium to address this issue during February 4–6, 2003 (9). Based upon the colloquium, several recommendations, including the lowering of creatinine value to < 2 mg/dL for a sample to be considered as "substituted," were proposed for revising rules and regulations related to the validity testing (3,4).

Criteria for urine specimen validity have been summarized in a review article published in 2000 (10). Ingestion of excessive amounts of water (3.785 L; 4 × 946-mL aliquots; 1 × 946-mL aliquot consumed each hour for 4 h) by human subjects has been reported to produce dilute urine samples based upon the criteria of < 20 mg/dL creatinine and < 1.003 specific gravity (11). A fluid ingestion study (643–6059 mL consumption of water, beverages, soup, etc. over a 12-h period) with 14 volunteers revealed erratic changes in the urinary creatinine concentration with specific gravity of ≥ 1.003 (12). In a human study involving ingestion of at least 2.37 L of fluid over a 6-h period, none of the urine samples satisfied the substitution criteria of creatinine ≤ 5.0 mg/dL and specific gravity ≤ 1.001 or ≥ 1.020; however, 73% of the participants produced at least 1 specimen that could be considered as "dilute" based upon creatinine < 20.0 mg/dL and specific gravity < 1.003 (13). While some studies have been published addressing specimen validity related concerns, well-designed, focused scientific studies on this issue in conjunction with body composition parameters are lacking. In the present study, effects of the consumption of water and 3 types of commonly used commercial soft drinks by human participants were evaluated with regard to their urine characteristics associated with workplace drug testing. Attempts were also made to define a relationship between changes in such characteristics with human body composition parameters.

MATERIALS AND METHODS

Human Subjects

A total of 24 healthy subjects (12 males and 12 females) between the ages of 25 and 35 yr participated in this study. Human subject participation was approved by the Institutional Review Boards of the University of Oklahoma Health Sciences Center (OUHSC), Oklahoma City, OK, and of the FAA's Civil Aerospace Medical Institute (CAMI), Oklahoma City, OK. These subjects were not on medications, with the exception of oral contraceptives and allergy remedies. However, the participants were asked to not take anti-allergy drugs on the days of the experiment.

Participant visits occurred between August 2003 and March 2006. Each subject visited the clinic 4 times for the experiments. The time spans over which these 4 visits occurred ranged from 4 to 43 d, with 3 extraordinary time spans of 98, 185, and 253 d.

Upon arrival at the OUHSC General Clinical Research Center (GCRC) for the initial visit, consent was obtained from the participants. Then, their body composition parameters were measured, which took an average of 1.5 h. Subsequently, subjects proceeded with liquid consumption and urine sampling.

Body Composition Parameters

Height, percent body fat, and resting metabolic rate (RMR) of the subjects were determined on the day of their first visit, but body weight was measured on each of the 4 visits (Table I). Percent body fat was measured by the dual-energy X-ray absorptiometry technique (HOLOGIC QDR 4500A, Delphi, Bedford, MA). RMR was measured by indirect calorimetry (MedGraphics, Cardiorespiratory Diagnostic Systems, Minneapolis, MN) after having the participant lie still on a bed for 30 min. Subjects were asked in advance to refrain from exercise in the 12-h period prior to the visit and to avoid strenuous activity when coming to GCRC.

Urine Samples

Participants arrived at GCRC at approximately 8:00 A.M. *nil per os* (NPO; nothing by mouth; by self-report) for the previous 12 h. All participants brought their first morning void urine samples (average collection time 7:00 A.M.) in urine sample collectors (Specimen Collector Commode, Medegen Inc., Ontario, CA) supplied by GCRC. For the morning sample (Sample 1), participants were instructed to place the collector's cap under the lid of the toilet and collect all first morning urine specimen, record volume, then pour through the collector's spout approximately 100 mL of the urine to a smaller container

Table I. Body Composition Parameters of Human Subjects Participating in the Study[*]

Participants[†]	Height (m)	Weight (kg)	Body Mass Index (kg/m^2)	% Body Fat[‡]	Resting Metabolic Rate (RMR)[§]
Male (n = 12)	1.84 ± 0.05 (1.77–1.93)	86.5 ± 11.2 (74.0–106.8)	25.6 ± 2.3 (23.1–30.2)	19.7 ± 5.1 (9.4–27.6)	1404 ± 390 (904–2425)
Female (n = 12)	1.63 ± 0.07 (1.52–1.78)	63.9 ± 14.2 (44.1–84.0)	23.8 ± 4.7 (17.6–33.9)	30.5 ± 7.1 (21.5–41.9)	1085 ± 257 (672–1604)
Male and female[**] (n = 24)	1.73 ± 0.12 (1.52–1.93)	75.2 ± 16.9 (44.1–106.8)	24.7 ± 3.8 (17.6–33.9)	25.1 ± 8.2 (9.4–41.9)	1244 ± 359 (672–2425)

[*]Values are mean ± standard deviation (SD). Numbers in parentheses below the mean ± SD values are the range.
[†]Age group: 25–35 yr.
[‡]Determined by the dual-energy X-ray absorptiometry technique.
[§]Kilocalories expended in a 24-h time period.
[**]Combined body composition parameter values of both male and female subjects.

(Kendall Precision Mid-Stream Urine Collector Kit, Tyco 2001 Healthcare Group LP, Mansfield, MA), which was also provided by the OUHSC Clinical Research Center. Subsequent samples were similarly collected at the Center. No preservatives were used in collecting the samples. Urine samples in the small containers were stored at 2–4°C.

After the first morning void sample (Sample 1), urine samples were collected immediately prior to drinking the liquid (Sample 2), immediately after drinking the liquid (Sample 3), at predicted stomach clearance (Sample 4) (14), and at first urge to void (Sample 5), totaling 5 time-point samples during each visit. Following the collection of samples, volumes were measured. Specific gravity was determined by using a DiaScreen 50 Urine Chemistry Analyzer (Hypoguard, Minneapolis, MN). This instrument provided the readings of the specific gravity values only up to the 3rd decimal place with the increment of 0.005 in the range of 1.010 to 1.025.

The obtained samples were subsequently hand delivered to CAMI with frozen gel bags in an insulated plastic box. All received samples at CAMI were stored at –20°C until they were sent for further analyses. The desired volume of each sample for additional analyses was 50 mL; however, that was not the case with all the acquired samples, particularly Sample 3. Where available, 10–15 mL of the urine samples in screw capped 20-mL glass culture tubes (Fisher Scientific, Pittsburgh, PA) were shipped to the Northwest Toxicology (Salt Lake City, UT)—a U.S. Substance Abuse Mental Health Service Administration (SAMHSA) accredited laboratory—for analyses. Samples were shipped with frozen gel bags in an insulated box by an air courier service for next-day delivery.

Included analytical parameters were associated with dilution, substitution, and adulteration of urine. The analytical panel included measurements of creatinine, specific gravity (if creatinine level < 20 mg/dL), pH, oxidants, glutaraldehyde, and soap (6). The methods used for these analyses were proprietary analytical methods of the accredited laboratory but were consistent with the SAMHSA accreditation guidelines.

Liquids Consumed

On each visit, the participants were instructed to drink 800 mL of their assigned liquid within 5 min; the consumption was timed with a stopwatch for accuracy. The liquid types were (A) water, obtained from a regular city drinking water supply tap and filtered (Brita Products Company, Oakland, CA); (B) a fully (3.2 volumes) carbonated, carbohydrate-rich beverage (100 g/L carbohydrate; 706 mOsm/L), Lemon-Lime Shasta (National Beverage Corporation, Ft. Lauderdale, FL); (C) a non-carbonated, electrolyte- rich beverage (60 g/L carbohydrate; 320 mOsm/L), Gatorade (Quaker Oats Company, PepsiCo, Chicago, IL); and (D) a lightly (1.15 volumes) carbonated beverage (83 g/L carbohydrate, 542 mOsm/L), Fanta Orange (Coca Cola Company, Atlanta, GA). For a carbonated drink, "1 volume" is equivalent to 1 L of carbon dioxide dissolved in 1 L of the drink at Standard Temperature and Pressure (15). The stomach clearance times for these liquids, at which urine Sample 4 was collected, were reported as 21, 107, 31, and 47 min, respectively (14). The participants were given tolerably cold beverages to comfortably complete drinking in 5 min. No ice pieces were added to the beverages.

Participants were randomized to begin with a beverage A, B, C, or D at the first visit, then followed the order of the beverages A, B, C, and D at subsequent visits. In other words, the subjects who started with the beverage C had the sequence of the drinks C, D, A, and B on consecutive visits. Six subjects began drinking experiments with A, 4 with B, 8 with C, and 6 with D.

Statistics

Descriptive statistics are presented as mean ± standard deviation (SD). Statistical significance was determined using Student's *t*-test for continuous measures (age, height, weight, body mass index, percent body fat, RMR) or chi-squared test for discrete measures (gender). Statistical analyses were performed with results on males and females combined and on males and females separately. Calculations were performed by using Microsoft Office Excel 2003 (Redmond, WA) or a Texas Instruments TI-60 Advanced Scientific Calculator (Texas Instruments Professional TI-60 Guide Book 1986, Lubbock, TX).

RESULTS AND DISCUSSION

Twenty-four subjects of diverse ethnic backgrounds participated in the study: 2 African Americans, 2 Asians, 14 Caucasians, 2 Hispanics, and 4 Native Americans. Average values of various body composition parameters are given in Table I. The values of the parameters were consistent with those found in the general population: Percent body fat was greater in females than in males, and metabolic rate was higher in males than in females. The number of collected urine samples with sufficient volume for analysis was 469 of the expected 480 (24 subjects × 4 drink types × 5 time points) samples. There were 10 instances where the sample volume was zero because urine could not be voided by the participant; at 1 instance, no successful analysis could be performed. These 11 samples were associated with the sample collection just after drinking the 800-mL liquid—that is, with Sample 3. The time

allowed for liquid consumption was 5 min. Therefore, the time gap between the collection before drinking the liquid (Sample 2) and after drinking the liquid (Sample 3) was short. This short time restriction also resulted in the collection of relatively smaller volumes for Sample 3. Typically, they were approximately 7% of the morning void samples (Table II). Thereafter, the volumes of Samples 4 and 5 increased to 36% and 46%, respectively, relative to the volumes of the morning void samples. The volumes for Sample 4 were dependent upon the clearance time of the respective liquids. For example, the sample volume was less (approximately 9% of the morning void sample volume) with water (A) which had a reported stomach clearance of 21 min and it was more (approximately 87%) with a fully carbonated, carbohydrate-rich beverage (Lemon-Lime Shasta; B), which had a reported stomach clearance of 107 min (14).

Due to the limited volumes of collected samples, only 376 of the 469 samples were further analyzed for parameters associated with dilution, substitution, and adulteration. Of the 376 samples, 199 were from male subjects and 177 from female subjects. None of these 376 samples was positive for oxidants (nitrite, chromium VI, iodine, peroxide, and bleach) or for glutaraldehyde and soap (6). The absence of any adulterant was consistent with the pool of volunteer subjects who obviously had no motivation to adulterate their urine samples.

In accordance with the Department of Health and Human Services (DHHS) guidelines, findings from the drug analysis of a urine specimen with a pH value of ≥ 3.0 and < 4.5 or ≥ 9.0 and < 11.0 could be reported as invalid results (3,6). In the present study, the pH values of the 376 samples were determined to be normal, ranging from 4.5 to 8.7, with an exception of a morning void sample that had a pH value of 9.1 and creatinine concentration of 49 mg/dL. This sample, in accordance with the DHHS guidelines, could have been called a specimen with invalid results (6). However, the declaration of the drug analysis results from a urine sample with pH ≥ 9.0 to be invalid must be based upon the final decision of the Medical Review Officer, after evaluating all possible medical scenarios of the urine sample donor. In regard to this high pH value, it must be emphasized that the sample was from the morning void urine of a female volunteer, was refrigerated or frozen prior to the pH determination, and there was no apparent motivation for the subject to alter pH. The observed high pH of the sample might be an isolated incident, particularly when other samples collected from the same volunteer later in the day and with other fluid load experiments were within the normal pH range. It is notable that none of the urine samples collected after the fluid load was outside of the valid sample pH range.

Based upon the DHHS guidelines (6), none of the 376 samples analyzed fell under the category of "substituted." However, 36 of 376 (10%) samples had creatinine concentrations < 20 mg/dL but ≥ 2 mg/dL, and 27 of these low creatinine samples had specific gravity < 1.0030 but > 1.0010 (Table III). The remaining 9 samples had specific gravity ≥ 1.0030. Thus, 27 of the 376 urine samples could be considered "dilute" per DHHS guidelines. All 27 dilute samples were collected after the fluid load at the respective stomach clearance of the liquid (Sample 4) and/or at first urge to void thereafter (Sample 5). Twenty-one (78%) of 27 samples were collected at the time of urge (Sample 5). Interestingly, 20 (74%) of 27 dilute samples were collected from female participants. It should be further noted that 6 (50%) of 12 male subjects and 8 (67%) of 12 female subjects produced at least 1 "dilute" specimen (Table III). These specific observations suggest that females, in comparison to males, have a higher potential to produce urine that could fall in the category of "dilute." Females also have a lower muscle mass and lower creatinine values in general; thus, this is likely an additional reason why more females produced dilute urine.

The time interval between the collection of the urine samples and their analyses for creatinine determination was 12–494 d. Of the 96 experiments (24 subjects and 4 liquids), there were 33 experiments wherein the collection and analysis time interval was > 100 d. There were 26 experiments in which the urine creatinine concentration in at least 1 sample was < 20 mg/dL but ≥ 2 mg/dL and specific gravity < 1.0030 but > 1.0010. In 9 of these 26 experiments, the sample collection and creatinine analysis interval was > 100 d. It should be emphasized that all collected urine samples were stored at 2–4°C or –20°C prior to the analysis and were shipped for analyses with frozen gel bags in an insulated box by an air courier service for next-day delivery. Therefore, the effect of the time interval between the collection and analysis on the concentrations of creatinine was minimal, as this bio-marker has been reported to be essentially stable for at least 2 yr if urine is refrigerated or frozen (16,17).

In general, the type of liquid consumed did not appear to have an effect on risk of a dilute sample over all participants (Table III). However, among males the types were restricted to water (A: 4 of 9 samples) and a lightly carbonated beverage (D: 3 of 9 samples). Among females, dilute samples were obtained following all liquid types (A: 2, B: 6, C: 7, and D: 5 of 27 samples).

For the body composition parameters, no statistically significant differences were found between participants

Table II. The Volume of Urine Samples Collected at Various Time Intervals During Fluid Load Experiments

Beverage[*]	Urine Volume (mL) at Various Sample Collection Time Points (n = 12)[†]				
	Morning Void (Sample 1)	Just Prior to Fluid Intake (Sample 2)	Just After Fluid Intake (Sample 3)	At Stomach Clearance (Sample 4)	At First Urge (Sample 5)
			Male Subjects		
Water (A)	354 ± 177 (65–600)	49 ± 27 (10–100)	27± 27 (0–110)[‡]	40 ± 29 (15–100)	170 ± 123 (30–450)
Lemon-Lime Shasta (B)	399 ± 183 (140–750)	65 ± 37 (0–120)[‡]	36 ± 22 (10–80)	315 ± 190 (90–625)	125 ± 87 (60–400)
Gatorade (C)	339 ± 191 (200–800)	88 ± 86 (20–350)	43 ± 29 (0–90)[‡]	65 ± 38 (20–150)	193 ± 145 (60–600)
Fanta Orange (D)	324 ± 170 (160–700)	63 ± 30 (25–125)	29 ± 25 (10–85)	121 ± 61 (40–205)	157 ± 75 (65–350)
			Female Subjects		
Water (A)	371 ± 193 (60–800)	63 ± 30 (20–120)	11 ± 10 (0–40)[§]	23 ± 16 (5–65)	113 ± 55 (35–220)
Lemon-Lime Shasta (B)	355 ± 165 (80–675)	66 ± 35 (20–140)	11 ± 9 (0–30)[¶]	337 ± 249 (60–800)	123 ± 63 (45–290)
Gatorade (C)	363 ± 189 (30–775)	87 ± 73 (10–300)	15 ± 10 (0–30)[¶]	37 ± 28 (12–100)	216 ± 110 (70–450)
Fanta Orange (D)	358 ± 220 (80–850)	88 ± 59 (15–230)	22 ± 21 (5[**]–75)	106 ± 62 (20–225)	213 ± 119 (10–425)

[*]Water (A); a fully carbonated, carbohydrate-rich drink (Lemon-Lime Shasta; B); a non-carbonated, electrolyte-rich drink (Gatorade; C); and a lightly carbonated drink (Fanta Orange; D).

[†]Values are mean ± standard deviation (SD) of 12 data values (n), including zero values. Ranges of those volumes are given in parentheses.

[‡]The data value of 12, including 1 zero value.

[§]The data value of 12, including 3 zero values.

[¶]The data value of 12, including 2 zero values.

[**]No successful analysis on this 5-mL sample.

Table III. Creatinine in Urine Samples of Subjects Where at Least 1 Sample had Creatinine < 20 mg/dL but ≥ 2 mg/dL

Subject Identification No. (Ethnicity)	Beverage*	Creatinine Analysis Interval (Days)	Urinary Creatinine (mg/dL)				
			Sample 1	Sample 2	Sample 3	Sample 4 (Specific Gravity)†	Sample 5 (Specific Gravity)†
			Male Subjects				
5303 (Hispanic)	Water (A)	494	42.5	109.7	124.7	58.8	14.1 (1.0019)
5303	Gatorade (C)	268	47.3	57.9	65.4	45.3	15.9
5303	Fanta Orange (D)	246	78.8	125.7	130.7	34.3	15.7 (1.0027)
9958 (African American)	Water (A)	37	330.4	30.3	–‡	22.6	8.4 (1.0016)
6370 (Caucasian)	Water (A)	352	144.7	189.9	103.3	74.8	13.3 (1.0025)
8576 (Caucasian)	Water (A)	71	162.2	294.4	–	266.6	19.1 (1.0028)
8576	Gatorade (C)	91	193.6	154.5	141.7	61.0	16.8
8577 (Caucasian)	Fanta Orange (D)	77	116.8	181.3	–	32.8	19.4 (1.0027)
8704 (Caucasian)	Fanta Orange (D)	186	122.6	82.1	53.4	17.1 (1.0022)	24.9
			Female Subjects				
9201 (Hispanic)	Water (A)	23	276.7	204.7	124.7	37.1	11.6 (1.0020)
9201	Lemon-Lime Shasta (B)	19	105.7	157.0	–	18.6	22.1
9201	Gatorade (C)	17	76.6	100.3	–	–	12.9 (1.0019)
9201	Fanta Orange (D)	12	–	88.0	–	54.1	14.0 (1.0021)
8556 (Asian)	Lemon-Lime Shasta (B)	110	64.8	125.9	–	11.7 (1.0026)	23.3
8556	Gatorade (C)	109	70.3	39.5	–	16.8	7.0 (1.0014)
8556	Fanta Orange (D)	108	31.5	34.3	–	9.9 (1.0025)	17.7
8981 (Caucasian)	Water (A)	37	48.8	90.3	–	66.1	8.7
8981	Lemon-Lime Shasta (B)	35	86.1	161.6	–	36.7	19.8 (1.0029)

Table III. (Continued)

8981	Gatorade (C)	39	83.4	159.4	151.0	–	19.4
8981	Fanta Orange (D)	38	58.2	134.3	–	84.4	16.6
5203 (Asian)	Lemon-Lime Shasta (B)	71	193.2	207.2	169.2	16.8 (1.0026)	187.0
5203	Gatorade (C)	94	232.8	278.1	145.0	82.2	15.8 (1.0029)
5203	Fanta Orange (D)	88	179.4	129.5	–	34.5	16.3 (1.0016)
9264 (Caucasian)	Gatorade (C)	31	109.9	137.8	–	118.3	17.0 (1.0028)
9264	Fanta Orange (D)	25	69.4	76.6	–	29.0	15.9
9473 (Native American)	Water (A)	17	72.6	103.1	–	–	12.7 (1.0025)
9473	Lemon-Lime Shasta (B)	14	113.7	74.2	–	15.8 (1.0026)	15.4 (1.0027)
9473	Gatorade (C)	13	96.2	41.3	–	41.1	11.3 (1.0019)
9473	Fanta Orange (D)	48	134.7	59.4	–	22.2	9.4 (1.0016)
5177 (Caucasian)	Gatorade (C)	94	122.0	167.0	–	–	14.0 (1.0024)
5177	Fanta Orange (D)	109	60.7	97.9	–	43.2	9.7 (1.0024)
5213 (Native American)	Lemon-Lime Shasta (B)	71	109.4	128.5	118.9	14.0 (1.0024)	42.2
5213	Gatorade (C)	68	84.2	162.9	–	63.1	9.1 (1.0016)

[*]Water (A); a fully carbonated, carbohydrate-rich drink (Lemon-Lime Shasta; B); a non-carbonated, electrolyte-rich drink (Gatorade; C); and a lightly carbonated drink (Fanta Orange; D).

[†]Specific gravity values are shown in parentheses. Any sample with creatinine < 20 mg/dL but ≥ 2 mg/dL without a specific gravity value in parentheses means that the sample had a specific gravity value of ≥ 1.0030.

[‡]Insufficient amount of sample to perform analysis.

whose samples met the dilution criteria (creatinine < 20 mg/dL but ≥ 2 mg/dL and specific gravity < 1.0030 but > 1.0010) and those that did not. For male participants, the largest difference was for RMR, where males with at least 1 dilute sample had a 29% higher RMR and had 11% lower percent body fat ($p > 0.05$). For female participants, the largest difference was for weight, where females with at least 1 dilute sample weighed 20% less and were 8% shorter ($p > 0.05$). To show any difference as statistically significant may require a study with a larger subject sample size.

CONCLUSIONS

Findings from this study clearly suggest that obtaining a dilute urine sample from a donor does not necessarily indicate that the sample was intentionally diluted; it could be the result of natural physiological responses of the donor. In addition, individuals with higher resting metabolism (usually younger, trimmer, and more muscular) have a greater potential for producing dilute urine specimens than individuals with lower resting metabolism. Certainly, in addition to the amount and type of fluid intake prior to the urine specimen collection, the role of factors—such as dietary habits, ethnic origin, health-related treatments, working conditions, and/or genetic differences—in the production of dilute urine cannot be ruled out. For this very reason, the 107th U.S. Congress asked the DOT to study the effects of these factors on drug and alcohol validity testing (8,9). The findings from the present study emphasize that dilute samples must be carefully evaluated by the regulatory authorities in consideration with the entire physiological and personal spectrum of dietary and personal habits and genetic differences affecting the characteristics of urine collected from a particular donor. Such evaluation must also include the necessity to inquire when (and how much of) any liquid was consumed by the donor before donating the urine sample. These steps will help to avoid false accusations of providing a "dilute" urine sample.

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